Use of Chlorophyll Fluorescence Techniques to Detect Stresses in Corn

USDA-ARS at University of Nebraska - Lincoln

J.F. Shanahan*, A. Luchiari, J.S. Schepers, S. Johnson, and P. O'Neill

Introduction:

The Minolta SPAD™ chlorophyll meter (model 502) enables users to quickly and easily measure corn leaf chlorophyll content, which is strongly correlated to leaf N status of corn. (Fig. 1, picture of SPAD meter)

Since the SPAD meter has the potential to detect N deficiencies, it also shows promise as a tool for improving corn N management.

However, due to the conserved nature of leaf chlorophyll content, the SPAD meter may not be the most sensitive indicator of plant N stress.

Chlorophyll meters are more sensitive to crop N status than the human eye, but are not as sensitive as chlorophyll fluorescence.

Objective:

Compare chlorophyll meter and chlorophyll fluorescence techniques for detecting N and water stress.

Background:

Chlorophyll (CHL) is the major pigment associated with harvesting of solar energy by plants, with energy being converted to photochemical energy used in the assimilation of Co_2.

CHL fluorescence measures the efficiency of the light harvesting processes associated with photo-system II.

Fluorescence measurements have been shown to be very sensitive (pre-visual) indicators of various plant stresses such as water, nutrients, temperature, etc.

This technology is relatively new and in recent years has become much easier to utilize for field measurements.

The patented pulse amplitude modulation (PAM) principle (WALZ™ model PAM-2000) was used in our work to measure fluorescence parameters in field grown corn (Fig.1 and 2, PAM- 2000).

Earl and Tollenaar (1999) have shown that variation in thylakoid electron transport rate as determined with PAM fluorometry was associated with photosynthetic performance of maize hybrids under field conditions.

References:

Earl, H. J. and M. Tollenaar. 1999. Using chlorophyll fluorometry to compare photosynthetic performance of commercial maize (*Zea mays* L.) hybrids in the field. Field Crops Res. 61:201-210.

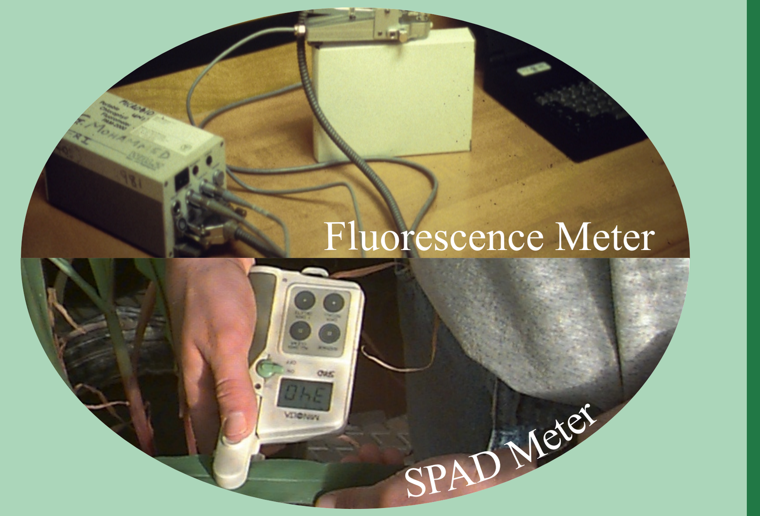

Figure 1. Picture of SPAD and fluorescence meters.

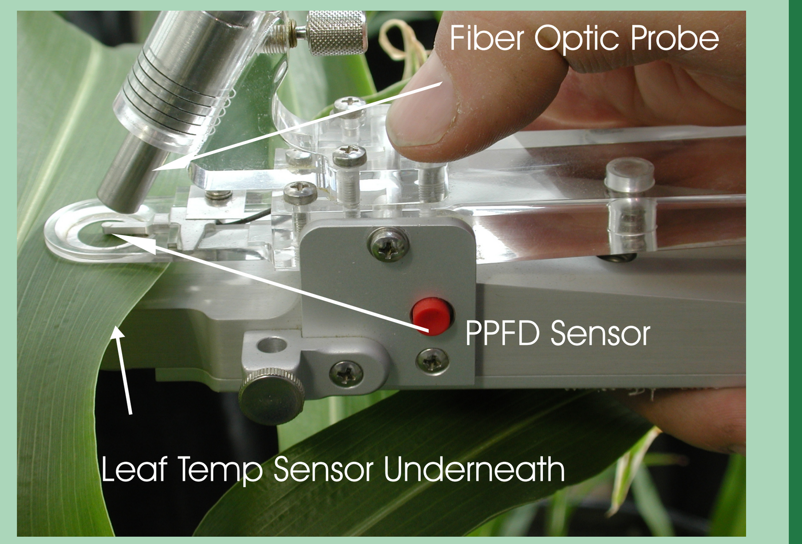

Figure 2. PAM-2000 leaf clip showing fiber optic, PPFD, and leaf temperature sensors.

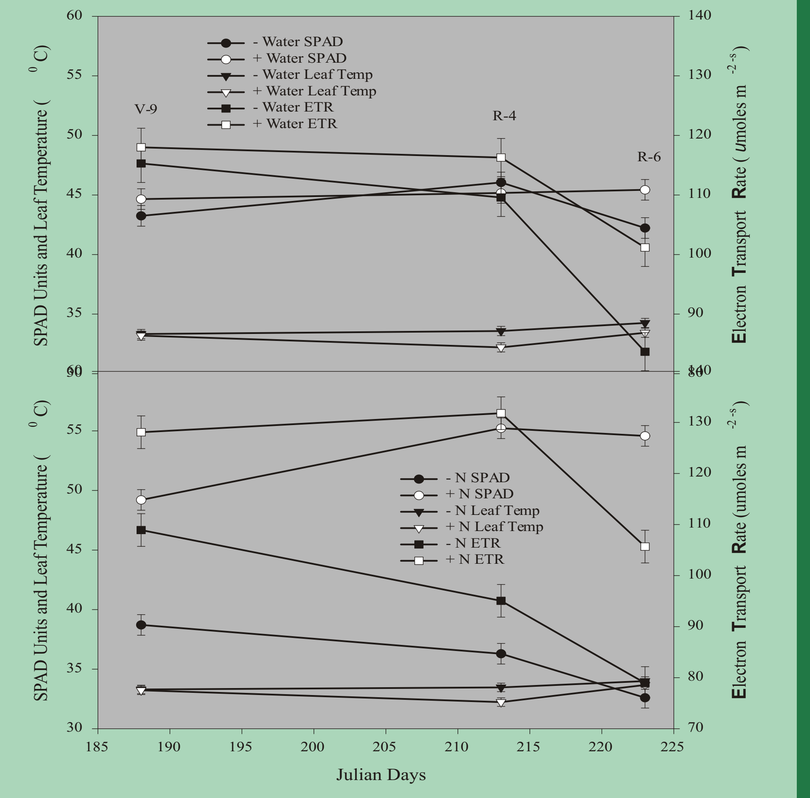

Figure 3. Effect of water and N stress on SPAD, leaf temperature, and ETR.

Study I (2000) Experimental Design and Procedures

Two Irrigation Levels, - Water (Stressed) and + Water (Non-stressed) as main plots.

Two Nitrogen Levels, -N (Stressed) and +N (Non-stressed) as split plots.

Twelve Hybrids (11 Pioneer and MO17/B73) as split-split plots (48 treatment combinations), with three replications.

SPAD and fluorescence measurements were made on three Julian days (188, 213, and 223) using 30 expanded leaves.

PAM-2000: Leaf Temp, photosynthetic photon flux density (PPFD), Photochemical quantum yield (F/Fm').

Electron transport rate (ETR) was calculated as: ETR = (PPFD x F/Fm' x Leaf Absorptance of PPFD x 0.4).

Where leaf absorptance of PPFD was determined from SPAD measurements as per Earl and Tollenaar (1999).

Grain yield by machine harvest and yield components, seed number (No. m^{-2}) and seed wt. determined at maturity.

Results:

AOV revealed significant water, N, and hybrid main effects as well as interactions among factors for grain yield, with water and N application increasing grain yields by 38% and 116% , respectively (not shown).

AOV revealed significant water, N, and hybrid main effects as well as interactions among factors for SPAD, leaf temperature, and ETR values across all three dates (not shown).

Differences in SPAD values between water levels were detected only on the final date, while differences in ETR and leaf temperature were observed much earlier, with ETR reduced and leaf temperatures increased by water stress (Fig. 3), indicating that fluorescence assessments were more sensitive than SPAD assessments in detecting water stress.

N stress drastically reduced SPAD and ETR values and increased leaf temperature on all measurement dates (Fig. 3)

Yield was more highly correlated with ETR values than SPAD values on R-4 growth stage, but not early (Tables 1&2).

Higher leaf temperatures from water deficit treatment during R-4 stage adversely affected ETR values (leaf photosynthesis), which reduced seed set and final grain yield (Fig 3. and Table 2).

In summary, ETR assessments were more sensitive than SPAD assessments in detecting water stress, but not N stress.

	Yield	Seed Wt.	Seed No.	SPAD	ETR	Leaf Temp.
Yield	1.000					
Seed Wt.	0.065	1.000				
Seed No.	0.993**	-0.035	1.000			
SPAD	0.895**	-0.030	0.893**	1.000		
ETR	0.678**	0.157	0.658**	0.719**	1.000	
Leaf Temp.	-0.147	-0.661**	-0.071	-0.086	-0.415	1.000

Table 1. Correlation matrix between grain yield and other independent variables on Julian day 188.

	Yield	Seed Wt.	Seed No.	SPAD	ETR	Leaf Temp.
Yield	1.000					
Seed Wt	0.065	1.000				
Seed No.	0.993**	-0.035	1.000			
SPAD	0.838**	-0.112	0.836 **	1.000		
ETR	0.878**	0.140	0.849**	0.842**	1.000	
Leaf Temp.	-0.771**	-0.361	-0.738**	-0.533*	-0.721**	1.000

Table 2. Correlation matrix between grain yield and other independent variables on Julian day 213.

Study II (2001) Experimental Design and Procedures

Two Irrigation Levels, - Water (Stressed) and + Water (Non-stressed) as main plots.

Adequate N level supplied to all plots.

Twelve Hybrids (11 Pioneer and MO17/B73) as split plots (24 treatment combinations), with three replications.

Using same procedures as in 2000, SPAD and fluorescence measurements were made on two Julian dates (212 and 219) with 30 expanded leaves.

Grain yield and yield components will be determined at maturity.

Results:

Similar to 2000 results, AOV revealed significant water and hybrid main effects as well as interactions among factors for SPAD, leaf temperature, and ETR values across dates (not shown).

On the first measurement date, the SPAD meter and PAM-2000 revealed no differences in leaf chlorophyll, temperature, or ETR associated with the water treatment (Fig. 4), and there were no associations among these variable on this date (Table 3)..

However, on the second date, water stress reduced SPAD values, increased leaf temperature, and reduced leaf photosynthesis as assessed by ETR measurements (Fig. 4).

As was observed in 2000, variations in ETR due to water and hybrid treatments were more highly associated with leaf temperatures than leaf chlorophyll (Table 4), indicating that fluorescence assessments were more sensitive than SPAD assessments in detecting water stress.

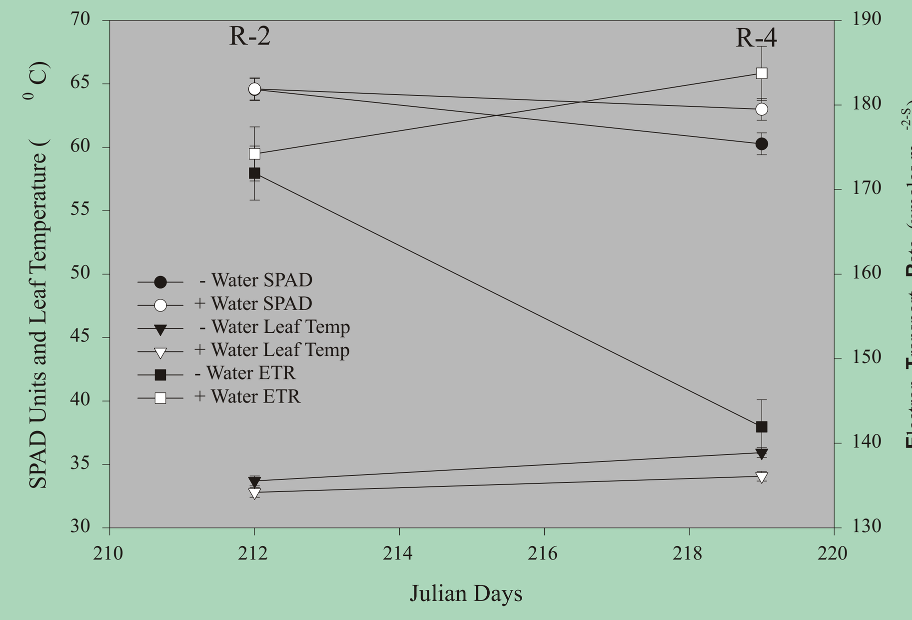

Figure 4. Effect of water stress on SPAD, leaf temperature, and ETR.

	ETR	SPAD	Leaf Temp
ETR	1.000		
SPAD	-0.197	1.000	
Leaf Temp	0.040	-0.145	1.000

Table 3. Correlation matrix between ETR and other independent variables on Julian day 212.

	ETR	SPAD	Leaf Temp
ETR	1.000		
SPAD	0.592*	1.000	
Leaf Temp	-0.907**	-0.611*	1.000

Table 4. Correlation matrix between ETR and other independent variables on Julian day 219.

Conclusions:

In summary, assessments of chlorophyll fluorescence appear to be more sensitive than the chlorophyll SPAD meter in detecting water stress in corn, and this technology appears to hold some promise for detecting grain yield differences among water, nitrogen and hybrid effects.